CCS Cost Estimation Methods in the Coal, Oil and Gas Sectors

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Capture Costs

- The cost of capture is generally expressed as:

Incremental cost to run for a given year / tonnes of CO_2 captured

Incremental cost is generally amortized incremental capital, O&M, fuel, etc required to capture CO_2

Incremental Cost in Power

Incremental cost can be established two ways:

1) By deriving the explicit costs to complete a CCS retrofit – Price out just the costs of the capture technology and the costs to run it (Works well for a retrofit) = Capex X CRF + O&M + Fuel per year

2) Compare the costs of a plant with CCS less the costs of a plant without CCS (Works well for a greenfield) =

$$(COE_{cap} – COE_{ref}) \times MWh_{cap}$$

Capture Cost Equation for Power

$$(COE_{cap} - COE_{ref}) \times MWh_{cap} / CO_2 \text{ Captured}$$

Effect of Power Derate

Cash Cost of CCS =

$(COE_{cap} \times MWh_{cap} - COE_{ref} \times MWh_{ref}) / CO_2$ Captured

- The numerator is the cash you would spend for both cases

However if the plant is derated society will replace this lost capacity without CCS

$(MWh_{ref} - MWh_{cap}) \times COE_{ref} / CO_2$ Captured

- The numerator is the cost associated with replacing the lost capacity. The sum of the two equations above gives the standard capture cost formula

Avoided Cost Power

- Generally power and steam are taken from a plant to provide the energy required to capture CO_2
- When a plant is derated society must replace the lost capacity – CO_2 associated with is it not avoided

CO_2 Captured CO_2 for Lost Power

$$(Int_{ref} \text{ X } MWh_{ref} - Int_{cap} \text{ X } MWh_{cap}) - (MWh_{ref} - MWh_{cap}) \text{ X } Int_{ref}$$

Or Avoided Mass of $CO_2 = (Int_{ref} - Int_{cap}) \text{ X } MWh_{cap}$

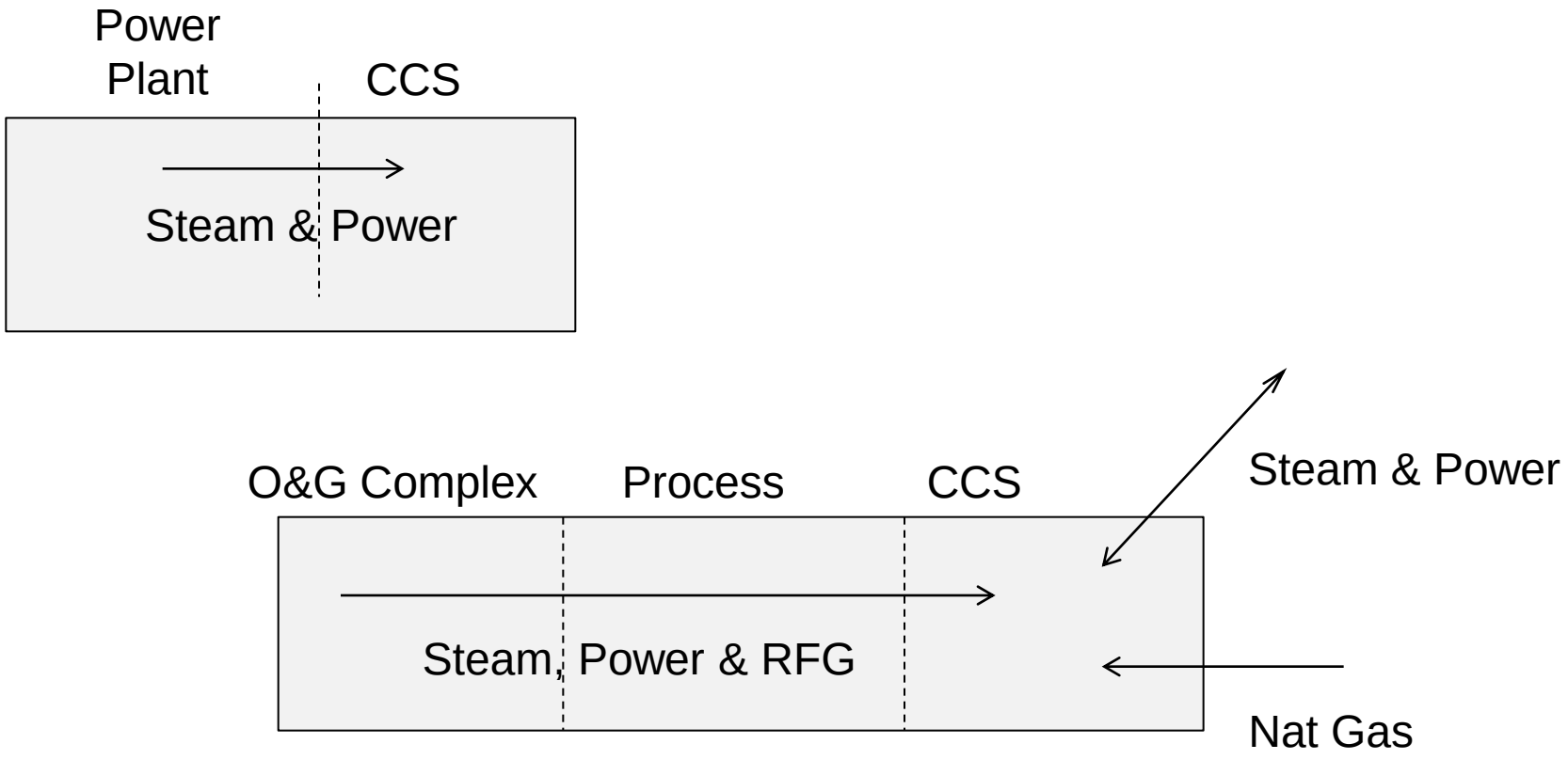
Avoided Cost =

$$(COE_{cap} - COE_{ref}) \text{ X } MWh_{cap} \text{ / } (Int_{ref} - Int_{cap}) \text{ X } MWh_{cap}$$

Oil and Gas Technologies

Oil and Gas Processes	Capture Technologies
OTSG	Solvent Scrubbing
Heaters and Boilers	Oxyfuel - CO2 Condensation
Fluid Cat Crackers	Fuel Cells (Molten Carbonate/SOFC)
Steam Methane Reformers	ATR – Low Carbon Fuel
NGCC / Cogens	Membranes (CO2, H2)
	Cryogenic Separation

Energy Requirement Cases



Issues with Oil and Gas

1) Establishing references for determining incremental cost can be hard
2) Estimating the incremental cost can be tricky
3) Determining the mass of CO_2 avoided can be difficult
4) Getting a good sense of how CCS will affect the cost of a product is difficult
5) Defining emission intensities for two commodities is complicated

1) References

A reference can be hard to establish for determining incremental cost and CO_2 emissions

- What is the reference for a polygen with CCS which produces both hydrogen and power?
  - A polygen without CCS
  - An SMR
  - An NGCC, SCPC etc
- What is the reference for an SOFC with CCS which produces power and steam?
  - An SOFC without CCS
  - An OTSG without CCS

Good References

- A good greenfield reference is generally the one you would build if you didn’t have to do CCS
- The cases with and without CCS should produce similar amounts of stuff to be comparable
- You may want to use more than one reference to complete the calculations
- However, many oil and gas studies assume a retrofit of an existing plant, so reference issues are not as important

2) Estimating Incremental Costs

Estimating the incremental cost can be tricky:

- In some cases when you install CCS some pieces of equipment such as air blowers, compressors, etc are no longer useful. Their cost can be avoided on a greenfield basis but not on a retrofit basis. (Oxyfuel)
- If steam used for CCS is taken from other plant processes, is a cost attributed to it?
- If power used for CCS is taken from elsewhere in the plant, is a cost attributed to it?
- If extra RFG is used as a fuel, is a value attributed to it?
- If less fuel (RFG) is used, is a value attributed to it?

Incremental Costs (con't)

- If the retrofitted process allows you to change feedstock, how do you account for this? (FCC)
- If the retrofitted process causes a decrease in output how do you account for this?
- For power the standard formula using COE accounts for the cost of derates. When using incremental costs for a CCS project, you may not know what the underlying plant costs is – so calculating the impact of a derate is not possible

3) Mass of CO_2 Avoided

What convention to use to determine mass of CO_2 Avoided?

- CO_2 Avoided = CO_2 Capture – CO_2 Power Used from Grid + CO_2 Credits for Power Produced – CO_2 from Extra Fuel Used (Steam)

OR

- CO_2 Avoided = CO_2 in Ref Case – CO_2 Emissions – CO_2 Power Used from Grid + CO_2 Credits for Power Produced

OR

- Change in COX / Change in GHG Emission Intensity (This one should only be used as a check, I do all three)

What Information Do You Have?

- If you are supplied with the incremental cost for completing CCS you might not know the CO_2 emissions for the reference case and therefore might not be able to use the second and third equation on the previous page
- In order to use the first equation you will need to know how much extra fuel is used compared to the base case – This can be hard to figure out if you are only given the characteristics for the case with CCS

Extra Fuel

- If a boiler is increased in size to provide additional steam required by the CCS process extra fuel will be used
- The GHG emission associated with this extra fuel should be deducted from the CO_2 captured to determine the mass of CO_2 avoided
- If a low carbon fuel is produced from natural gas, then extra fuel will be used – you will need to find a way to determine this

Will CO_2 from Steam be Captured?

- If CO_2 produced from a boiler is not captured this mass of CO_2 should be deducted from the mass captured to determine the avoided mass of CO_2
- However, if say 90% of this CO_2 is captured from the boiler then effectively only 10% of the CO_2 generated by the boiler should be deducted to determine the mass of CO_2 avoided
- The previous formuli account for this - check to make sure you get same results from several calculations

Use Appropriate Intensities

- If power is purchased from the grid for CCS then an emission intensity associated with the power produced should be used
- An emission intensity for steam supplied to capture CCS should be used or else the explicit amount of CO_2 used to produced steam or the fuel consumption and emission intensity of the fuel used to produce steam should be supplied
- The appropriate emission intensity for changes in fuel consumption should be used - natural gas is generally .05 t CO_2/GJ but not always

Complications

- If you replace an OTSG with say a molten carbonate fuel cell you can displace power otherwise purchased by the OTSG from the grid and sell excess power from the grid
- Transmission charges for sales and purchases may not be the same
- If power is sold to the grid one must use the appropriate grid intensity factor
- Some oxyfuel processes end up being more efficient or providing more waste heat for steam production reducing fuel consumption for the underlying process
- Sometimes an existing air blower is no longer operating saving power (Oxyfuel)

Complications (con’t)

- How do you account for an increase or decreases in throughput?
- How do you account for potential changes in feedstock slate?
  - For scoping studies you note it and indicated whether it will have a small or large positive or negative impact

4) Impact on Cost of Products

- Generally CCS is placed on a process which makes an intermediate commodity (steam, heat) not an end product (gasoline, power sold to grid)
- If you are working with incremental costs you may not be able to figure out the % increase in cost for your commodity
- It can be difficult to get a sense for how CCS will impact the cost of an end product particularly if you don't know how your intermediate product will be used
- It's hard in some cases to get a feel for how much CCS will impact costs

Levelized Cost

The levelized cost of a commodities could be:

- $/m3 for steam produced by OTSG/boiler – can be translated into $/bbl but might not have other costs to produce oil
- For SMR could translate costs into $/tonne of hydrogen
- For FCC could potentially translate costs into barrels of output
- Not sure what to use for a heater. Could use GJ of heat supplied or on GJ of fuel supplied - Could translate CCS cost into a price increase of fuel
- Similar issue for defining intensities

5) Defining Emission Intensities

If your capture technology produces both steam and power (Cogen, IGCC, Fuel Cells) how do you determine the emission intensities for each commodity?

- Set the emission intensity for one commodity to 0 and solve for the emission intensity of the other and vise versa
- Plot the values – the resulting line is the relationship between the two intensities
- Compare to base case emission intensity without CCS
- Sometimes it is not clear what commodity to use to define the intensity – Heaters?

Comment on Cement

- Many folks are planning to mineralize CO_2
- If they sell this mineral to the cement industry it will be calcined and all of the CO_2 stored in the mineral will be liberated!
- I have seen many projects pretending to store CO_2 this way
- Generally the economics don’t work if the mineral is landfilled

The End